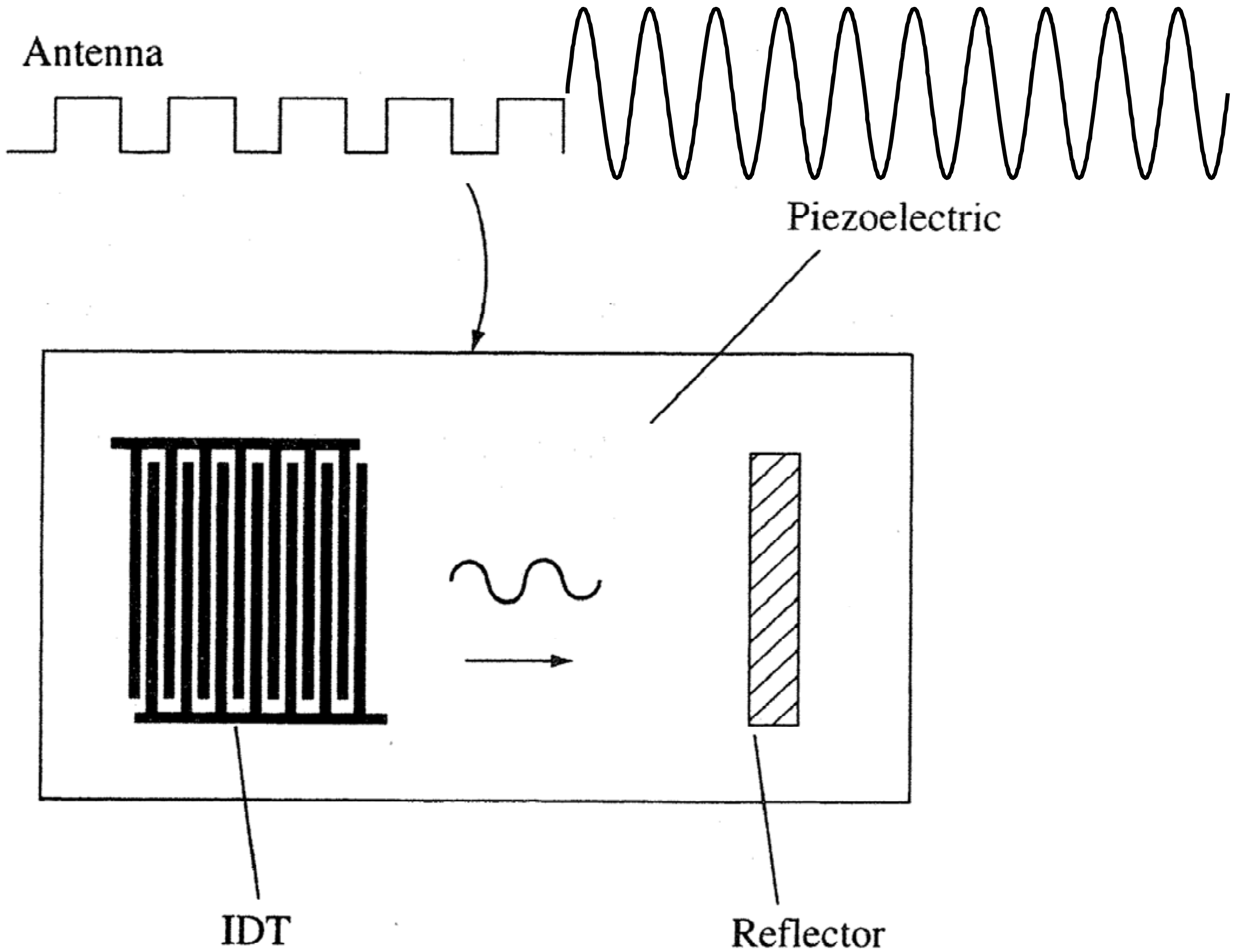
11. MEMS-IDT Microsensors

Radiation sensors – Microantenna

Wireless communication and powering of a SAW-IDT microsensors with a Al microantenna

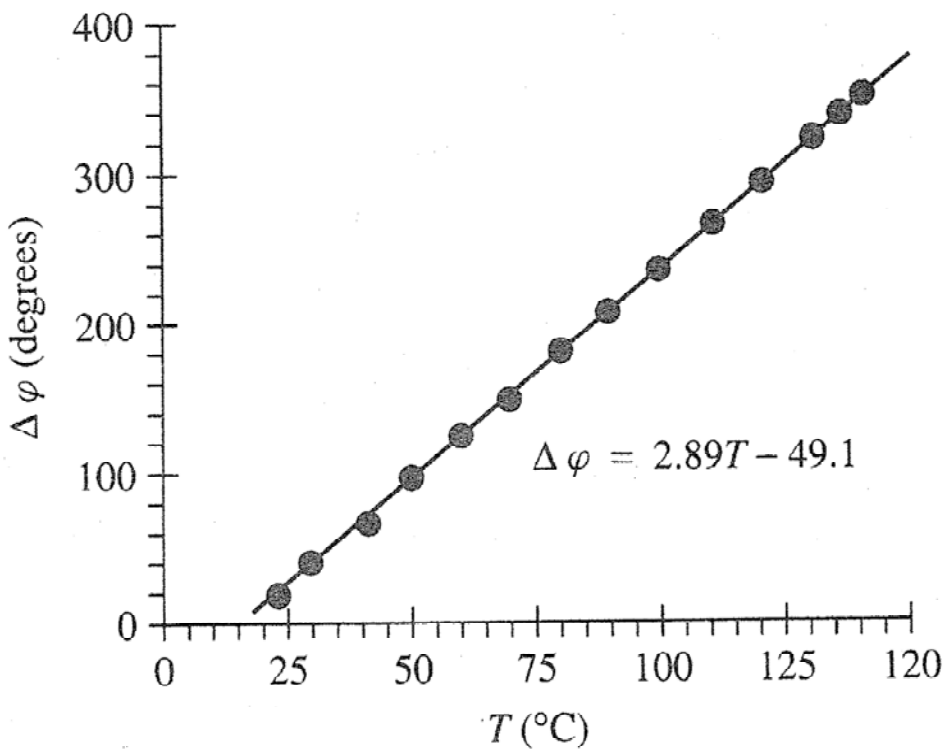


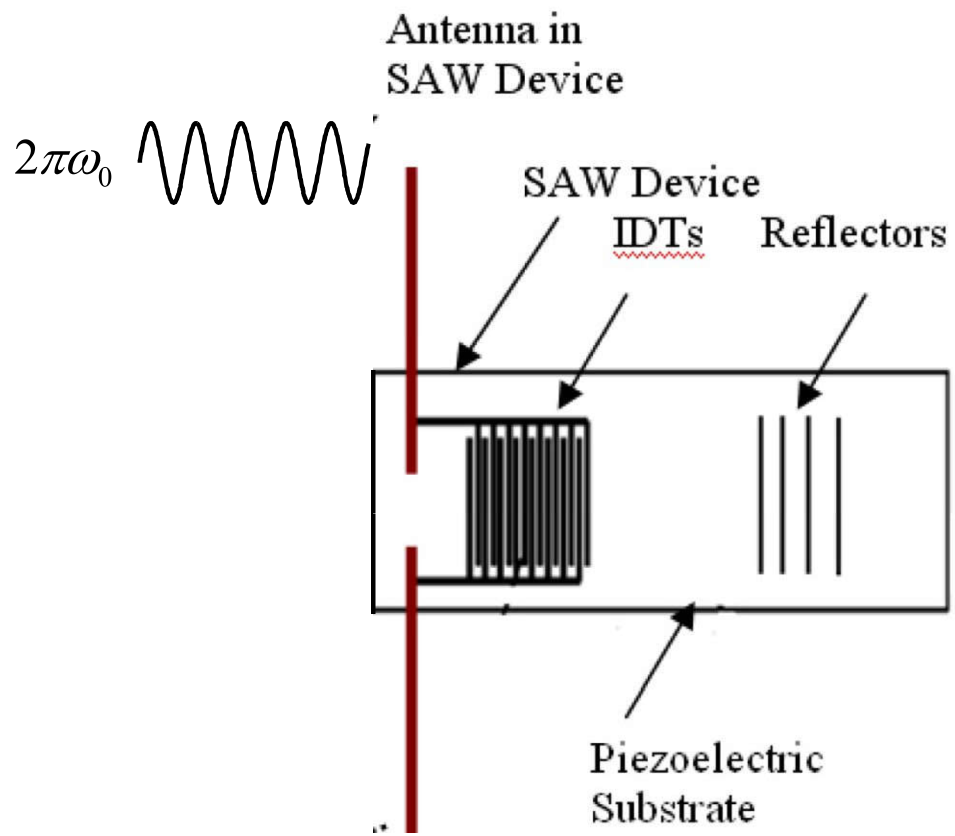
Thermal sensors – SAW temperature sensor

- a thin $LiNbO_3$ on top of a ceramic, glass, or silicon substrate
- 1-mask process to form a pair of interdigital electrodes (IDEs)
- IDEs connected to a small microwave antenna

$$\Delta\varphi \approx \omega_0 \alpha (\tau_2 - \tau_1) \Delta T$$

α: temperature coefficient of $LiNbO_3$

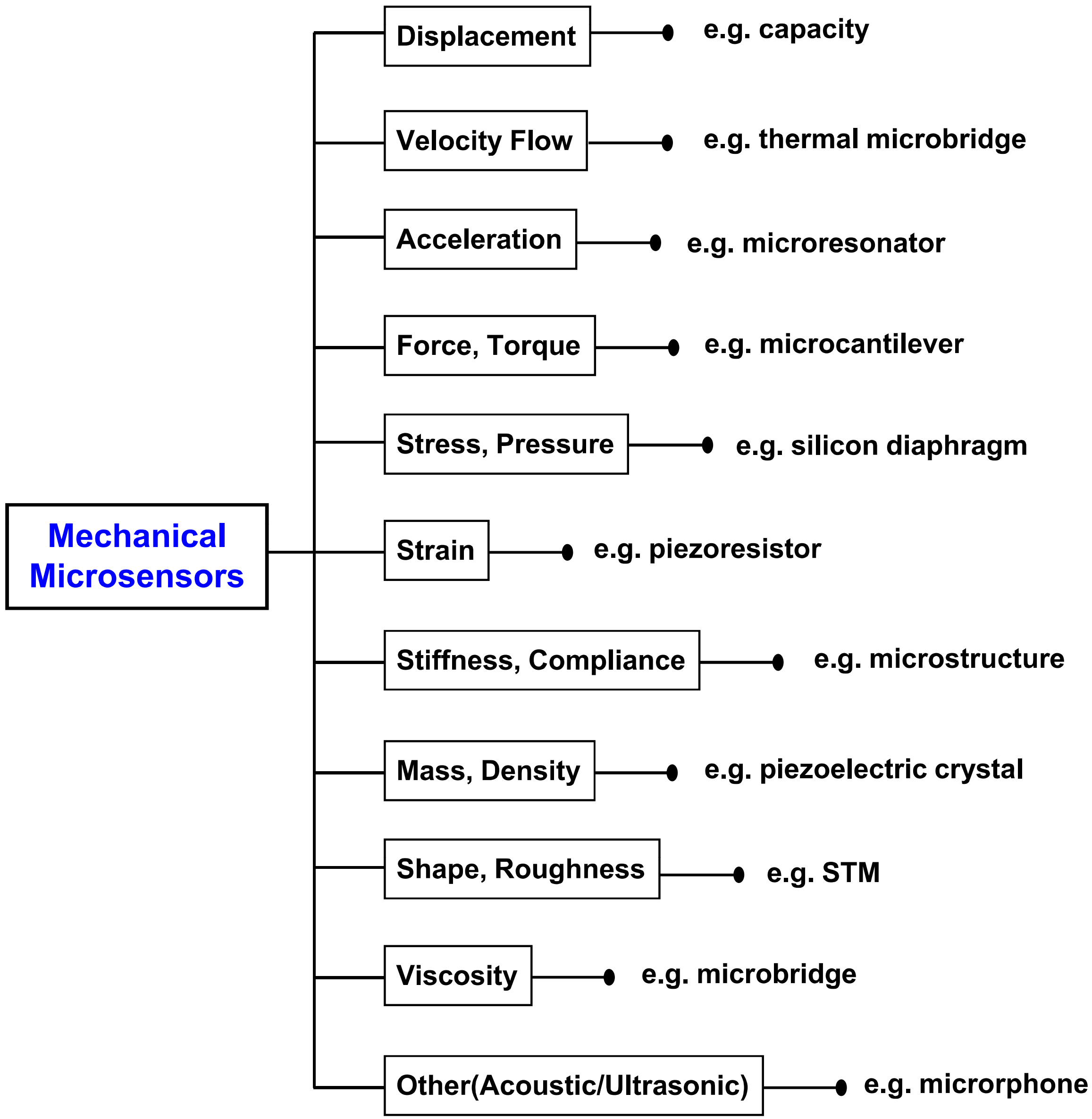




Mechanical sensors – Overview

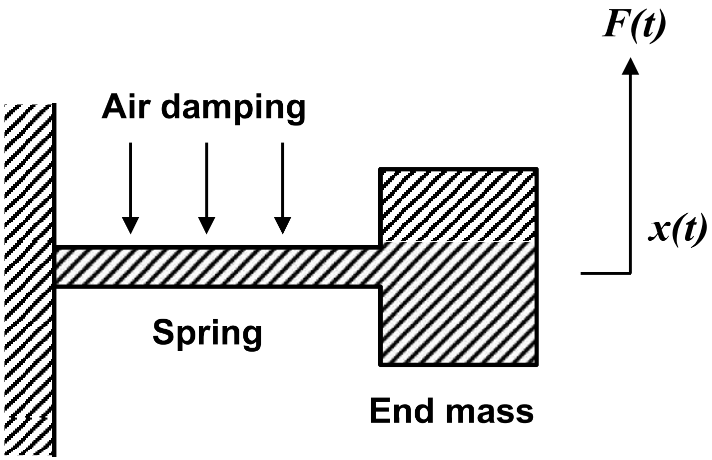
The most important class of microsensor, due to measurands and applications

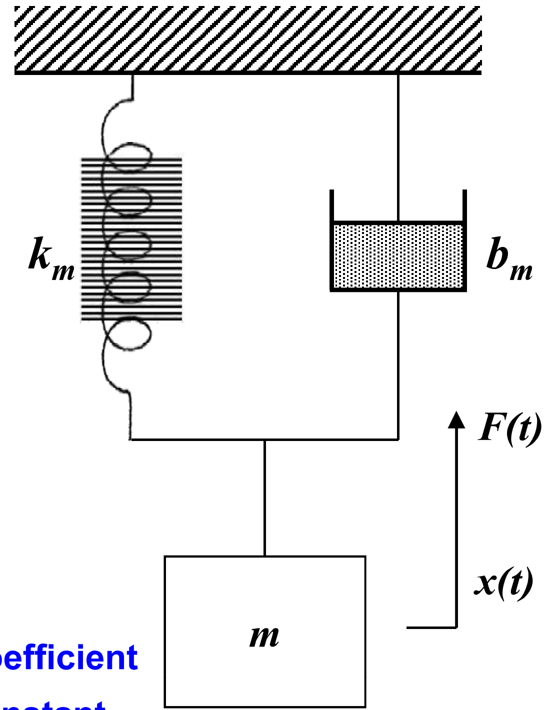
Acceleration
Acoustic energy
Altitude
Angle
Angular velocity
Angular acceleration
Compliance
Deflection
Deformation
Density
Diameter
Displacement
Elasticity
Flow rate (mass)
Flow rate (volumetric)
Force (simple)
Force (complex)
Frequency
Friction
Hardness
Impulse
Inclination
Kinetic energy
Length
Level
Mass
Momentum
Orientation
Path length
Pitch
Position
Pressure
Proximity
Reynolds number
Roll
Rotation
Roughness
Shape
Shock
Sound level
Stiffness
Tension
Thickness
Torque
Touch
Velocity
Vibration
Viscosity
Volume
Wavelength
Yaw
Young’s modulus



The dynamics of microstructures

one-dimensional lumped-system model





$$F_x(t) = m\frac{d^2x}{dt^2} + b_m\frac{dx}{dt} + k_m x$$

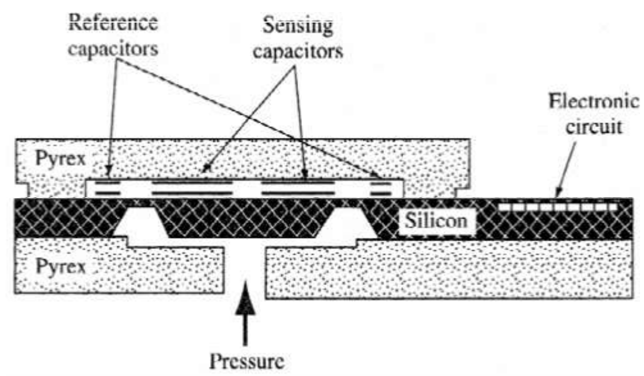
m: end mass
b_m: damping coefficient
k_m: stiffness constant

The types of transducer for a microstructure converts its deflection into an electrical quantity

1. Capacitive (electrostatic) pickup $\quad C = \frac{\varepsilon A}{d} \Rightarrow \frac{\delta C}{C} = \frac{\delta\varepsilon}{\varepsilon} + \frac{\delta A}{A} - \frac{\delta d}{d}$
2. Resistive (conductive) pickup $\quad \frac{\Delta R}{R} = K_{gf}\varepsilon_m$
3. Inductive (amperometric) pickup

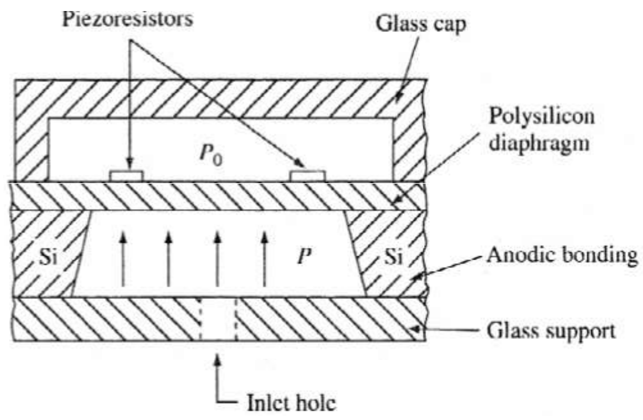
Two most important mechanical sensors

1. **Pressure microsensors – Manifold, Barometric, Fuel, Type, Suspension, etc.**



capacitive (single crystal silicon)

$$V_{out} \propto \Delta C \propto \Delta x \propto (P - P_0)$$



piezoresistive (polysilicon)

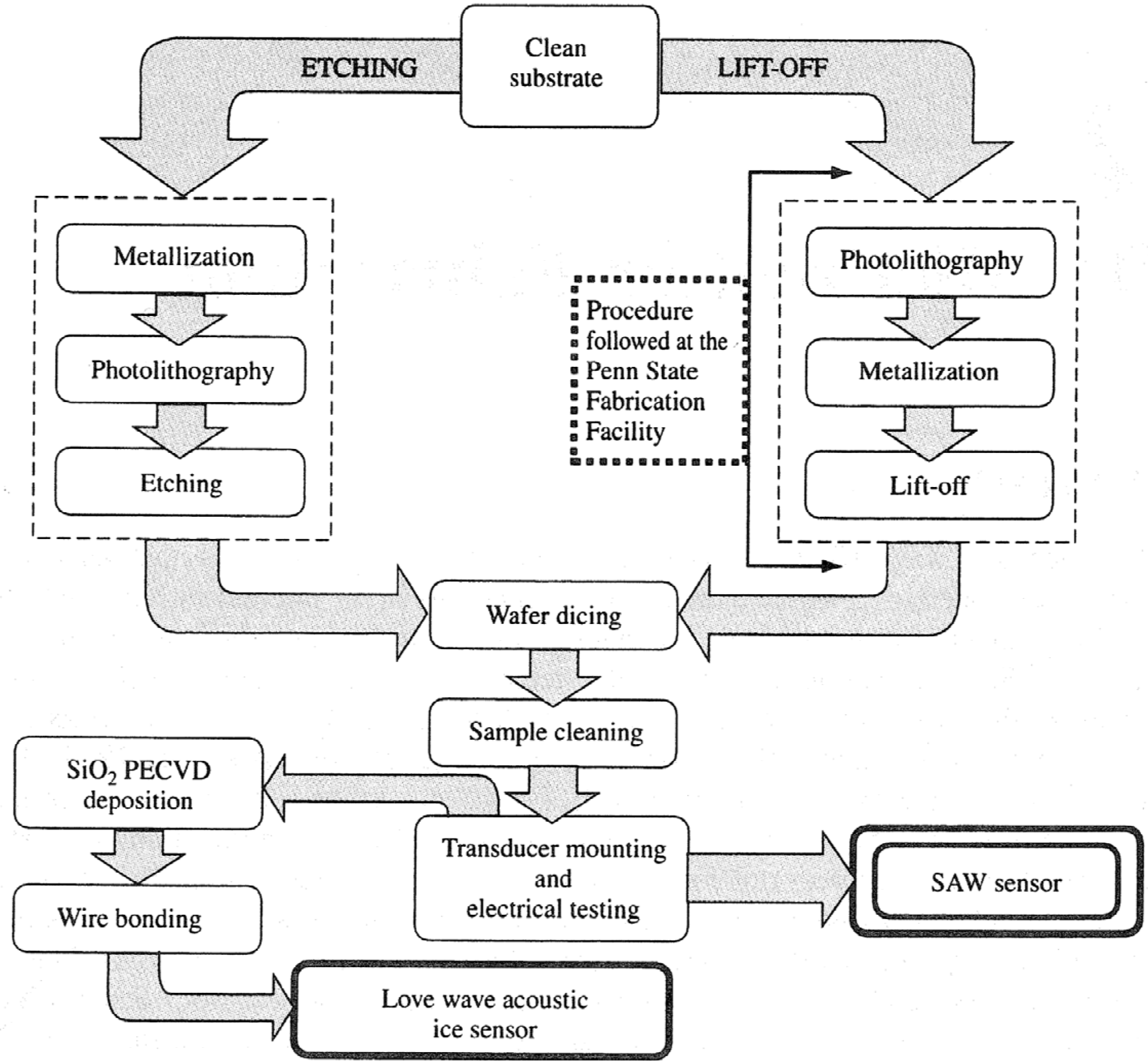
$$V_{out} \propto \Delta R \propto \Pi (P - P_0)$$

2. **Microaccelerometers – ABS, suspension, air bag systems.**

3. **Microgyrometers – Navigation**

Enormous growth in the automotive market!!!

Microsensors fabrication - IDTs



1. Mask generation

Pattern generator to produce a reticule, designed by L-Edit;

↓

Step-repeat-camera to create patterned arrays on a Cr-coated glass plate;

↓

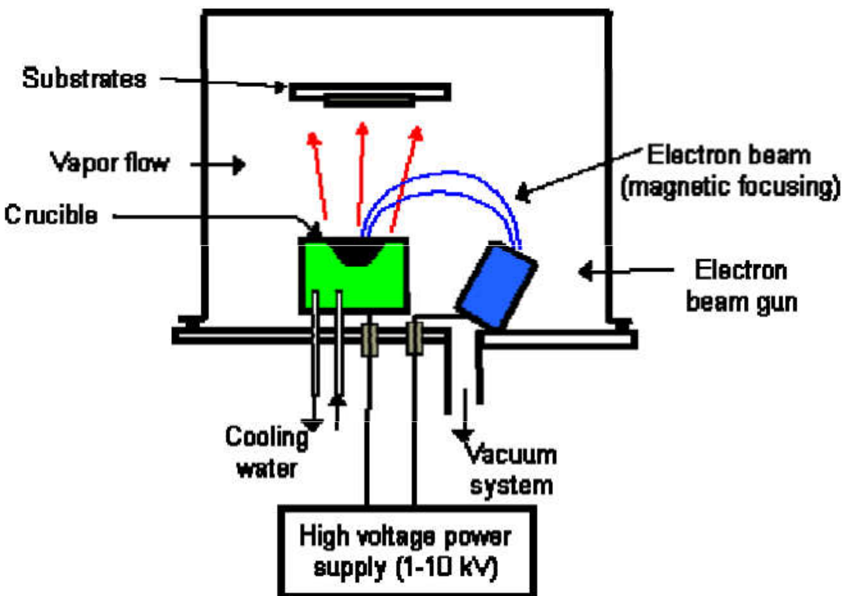
Develop and etch photoresist and Cr, respectively.

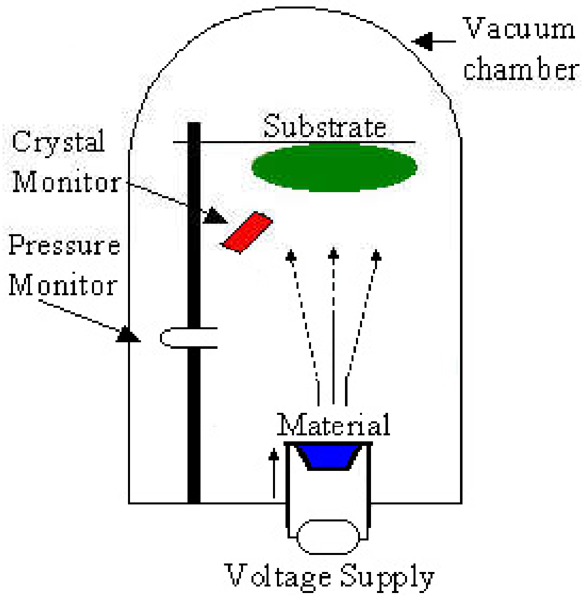
2. Wafer preparation

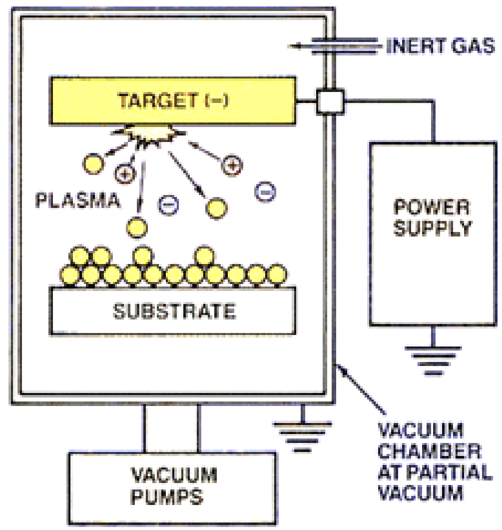
Effective cleaning of the wafers us a vital procedure.

3. Metallization

E-beam evaporator, thermal evaporation, sputtering







4. Photolithography

Clean metallized wafers

↓

Coat a photoresist layer, prebaked

↓

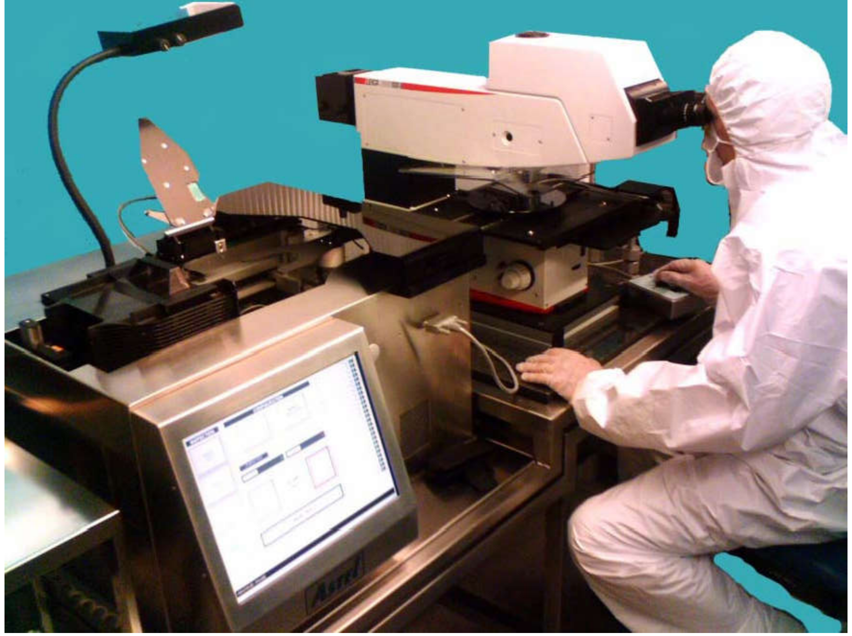
Align a Cr mask plate with a wafer

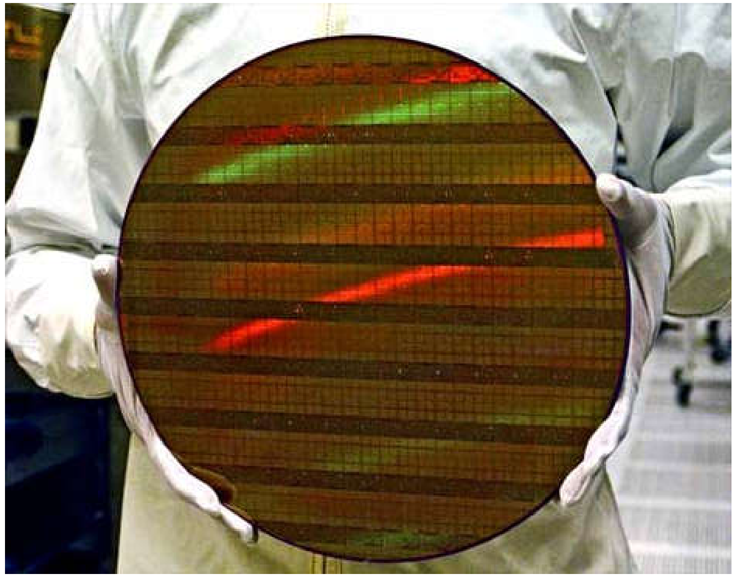
↓

UV expose and then developed, postbaked

↓

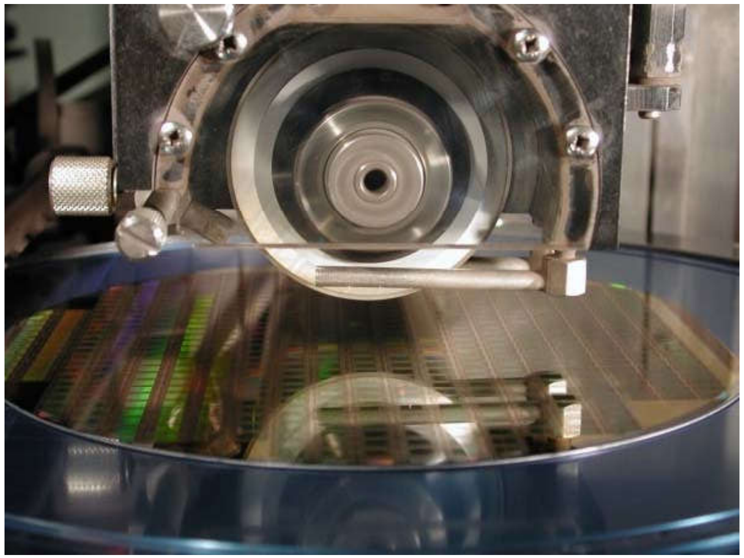
Chemical wet-etch unwanted metal on a wafer

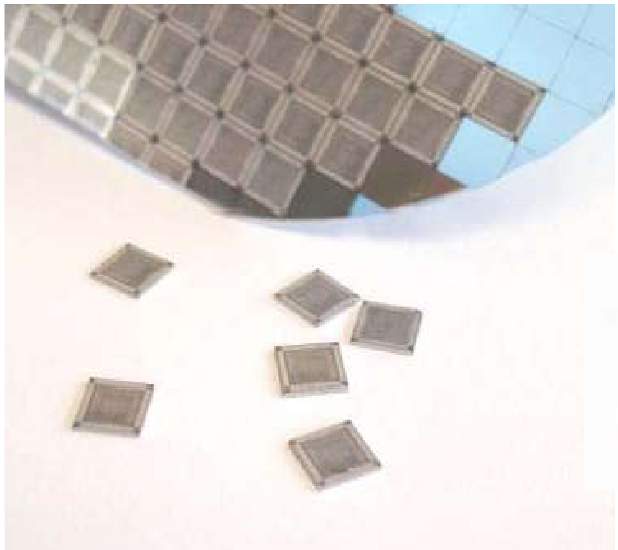


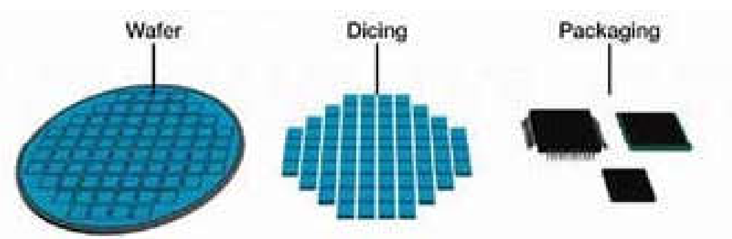


5. Wafer dicing

Cut into small, individual chips







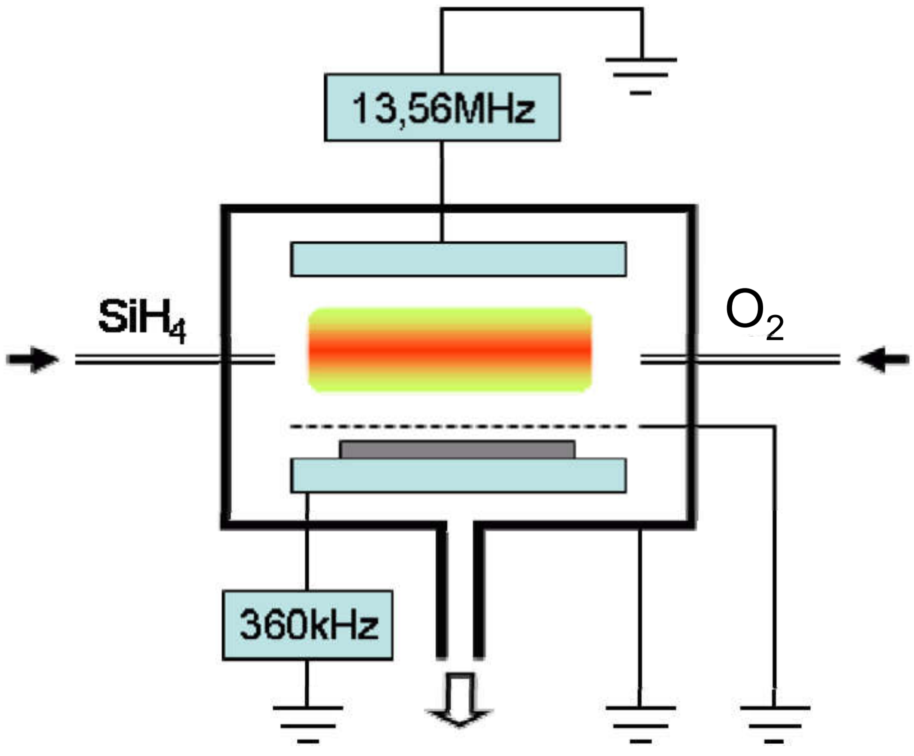
Deposition of waveguide layer

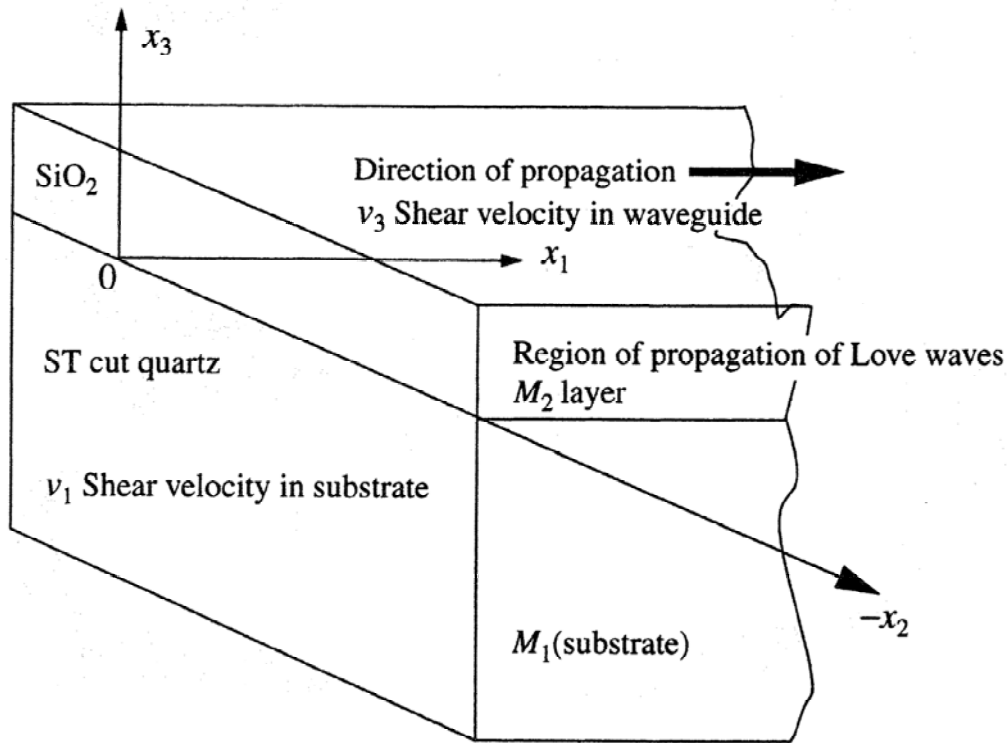
SiO_2 as a guiding layer on top of a piezoelectric wafer

1. The sputtering process, providing better step-coverage than evaporation.
2. Chemical vapour deposition (CVD) or plasma-enhanced chemical vapour deposition (PECVD), using oxidized silane gas (SiH_4) to form SiO_2 in O_2.

$$SiH_4 + O_2 \rightarrow SiO_2 + 2\,H_2$$

$$3\,SiH_4 + 6\,N_2O \rightarrow 3\,SiO_2 + 4\,NH_3 + 4\,N_2$$



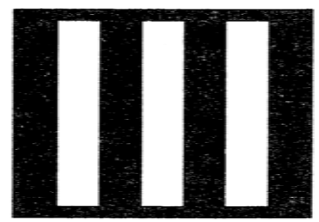


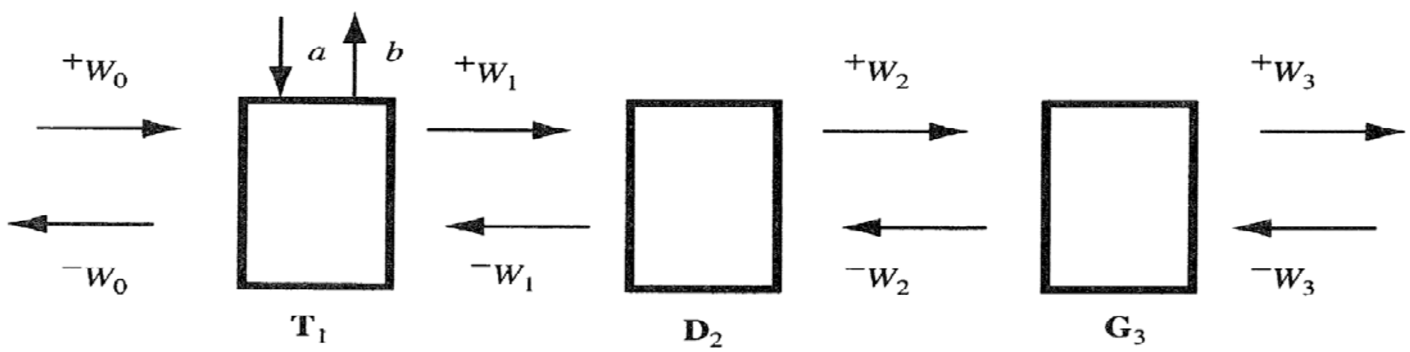
IDT Microsensors

Coupled-mode theory – SAW device modeling

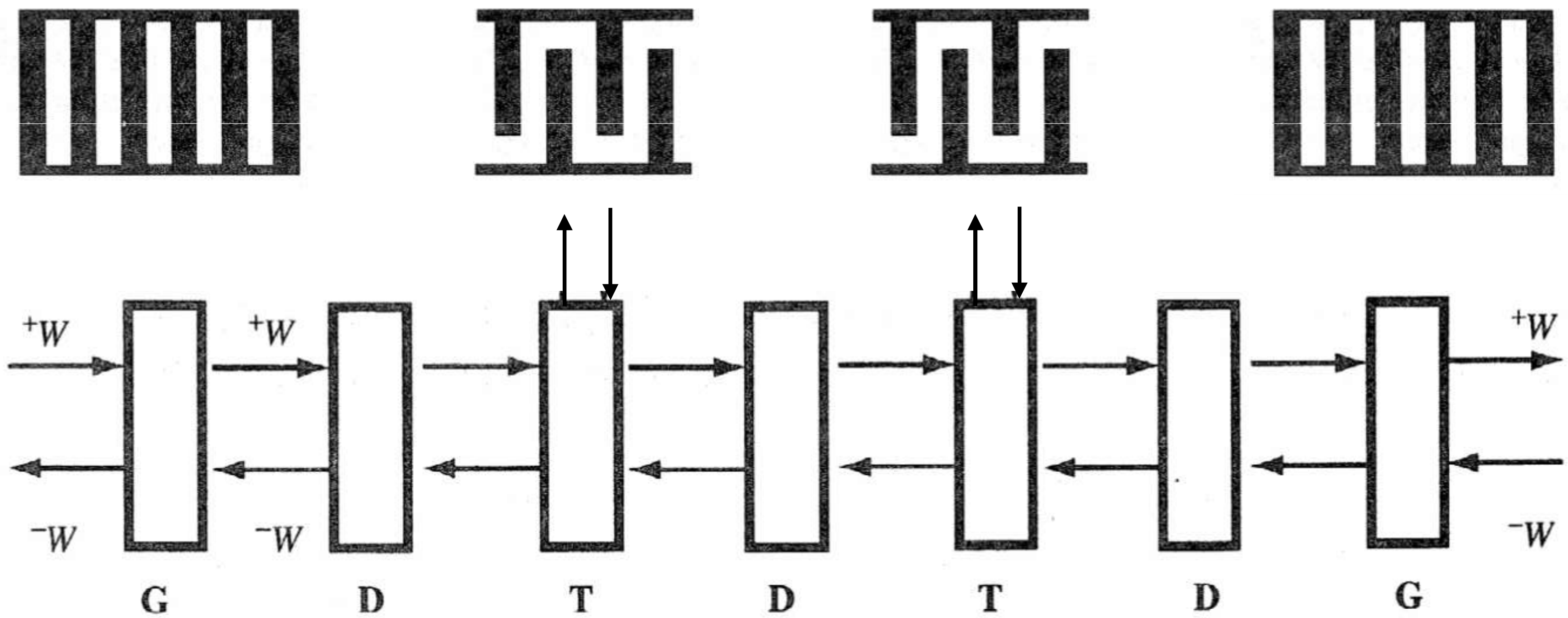
Three elements: IDT – T; spacing – D; reflector – G.

T: 3x3 **D: 2x2** **G: 2x2**

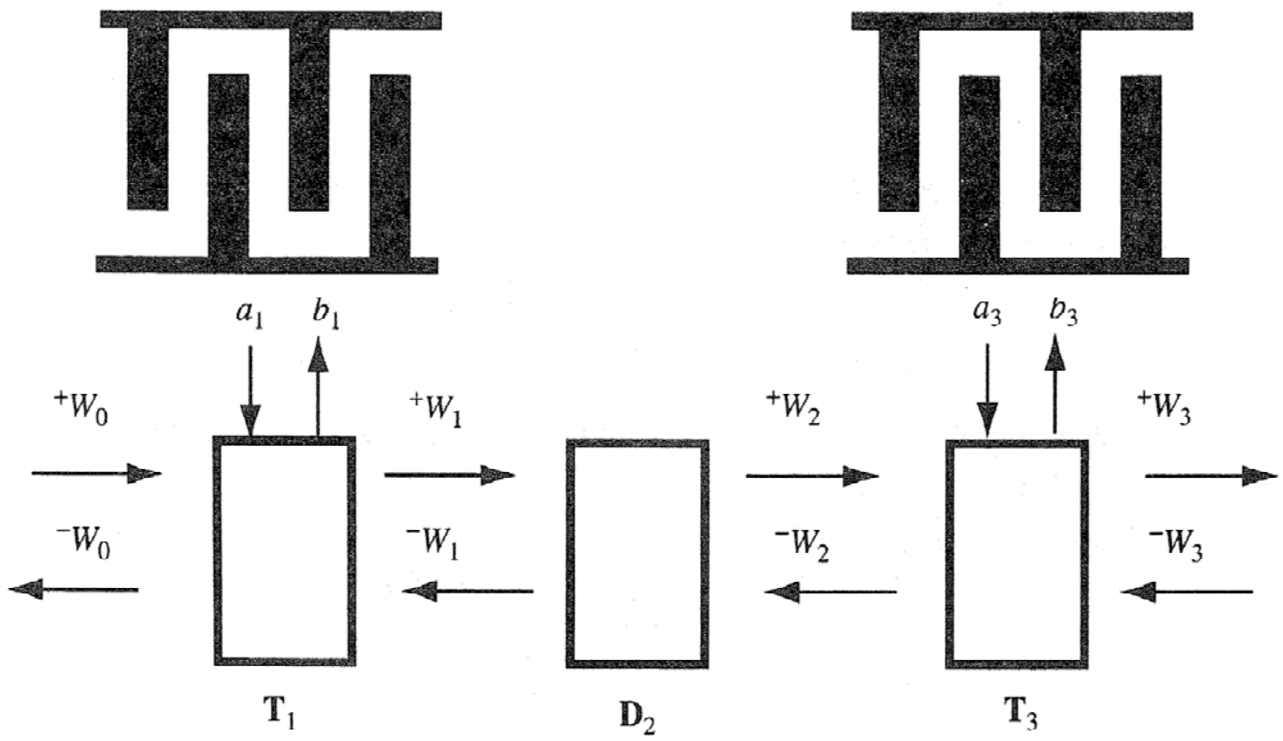




$$\begin{bmatrix} {}^{+}W_{n-1} \\ {}^{-}W_{n-1} \end{bmatrix} = [T, D, G]_n \cdot \begin{bmatrix} {}^{+}W_n \\ {}^{-}W_n \end{bmatrix}$$

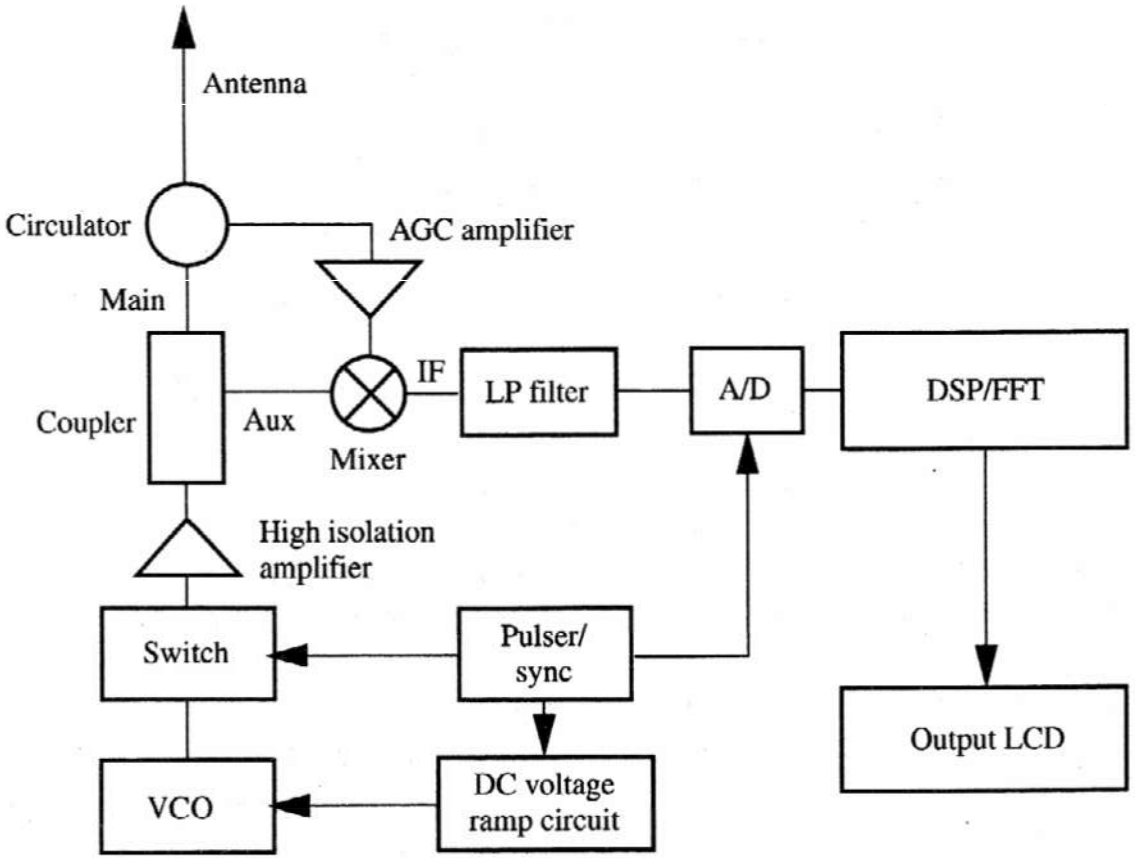


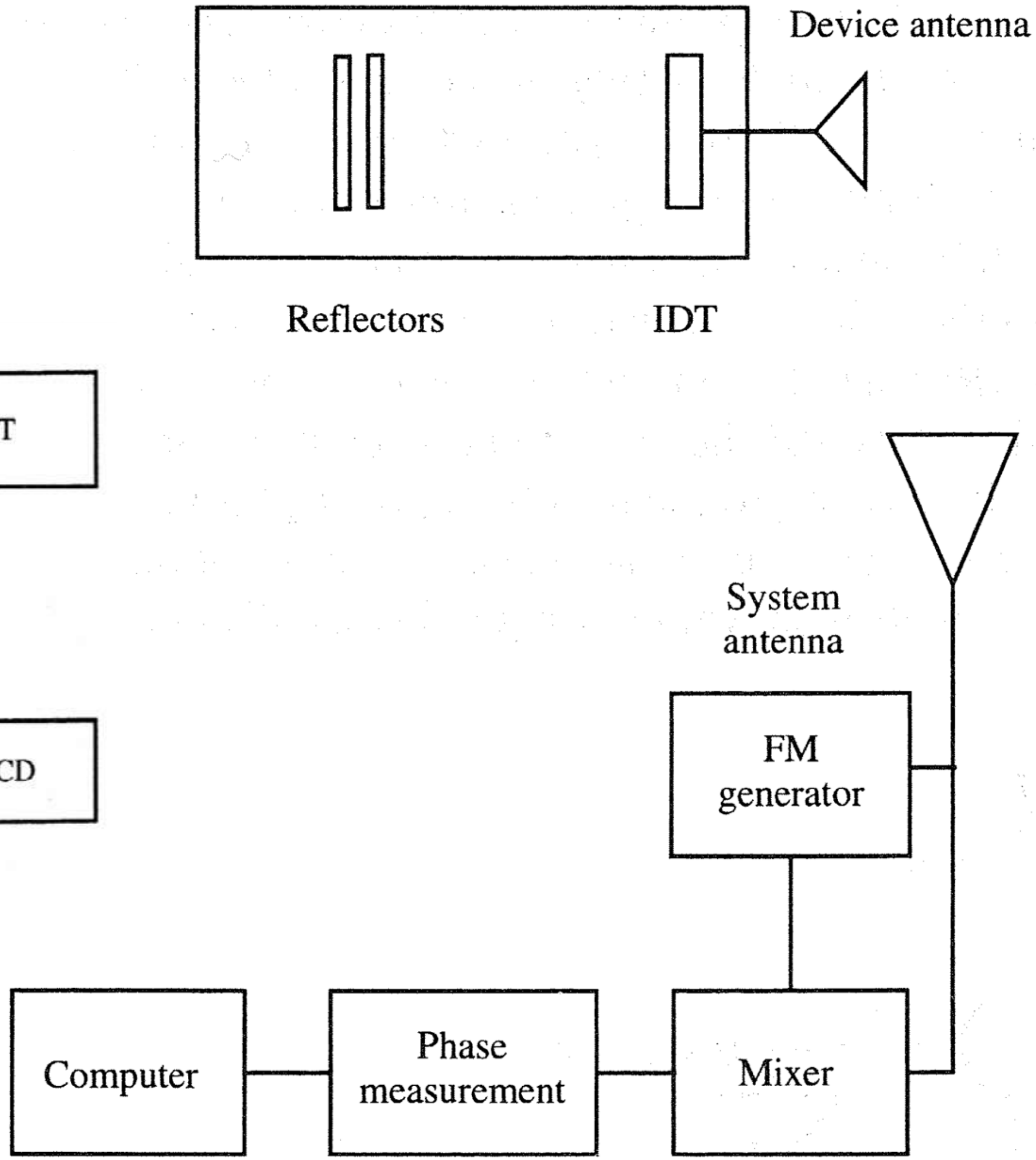
$$\begin{bmatrix} {}^{+}W_0 \\ {}^{-}W_0 \end{bmatrix} = [G_1]\cdot[D_2]\cdot[T_3]\cdot[D_4]\cdot[T_5]\cdot[D_6]\cdot[G_7]\cdot\begin{bmatrix} {}^{+}W_7 \\ {}^{-}W_7 \end{bmatrix}$$



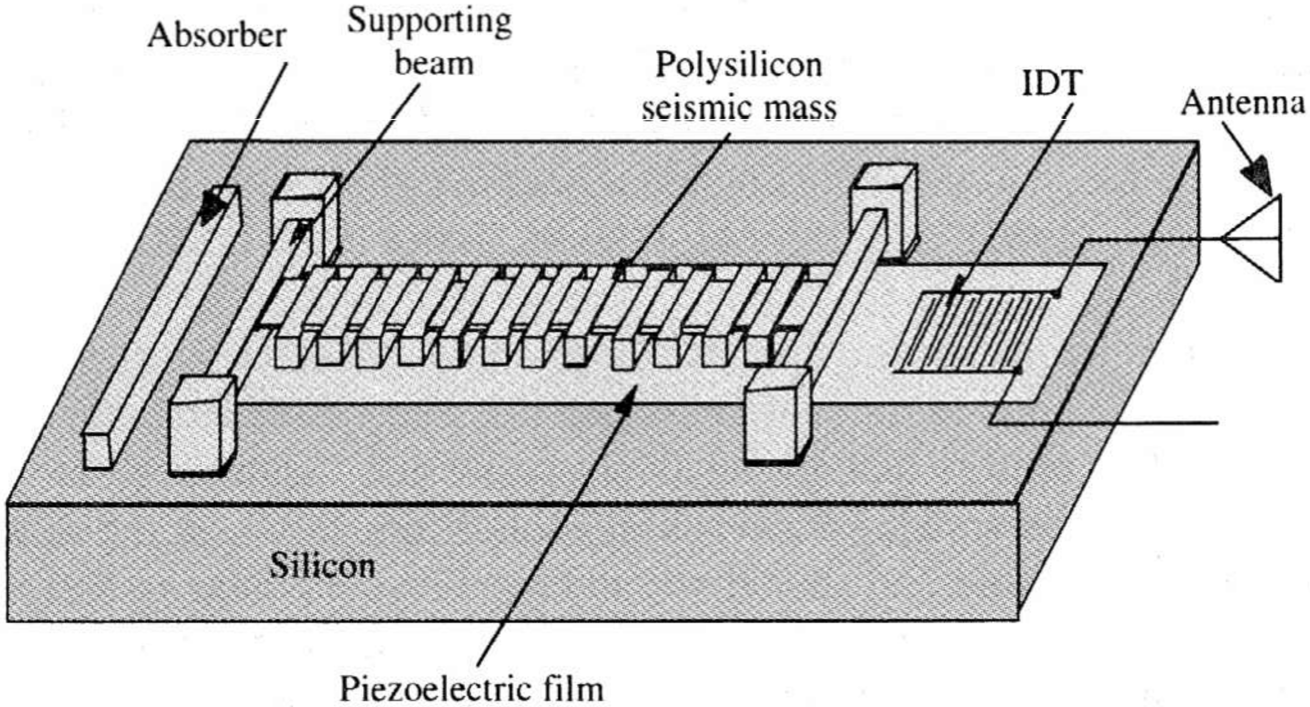
a_1
b_1
a_3
b_3
$^+W_0$
$^-W_0$
$^+W_1$
$^-W_1$
$^+W_2$
$^-W_2$
$^+W_3$
$^-W_3$
$\mathbf{T}_1$
$\mathbf{D}_2$
$\mathbf{T}_3$

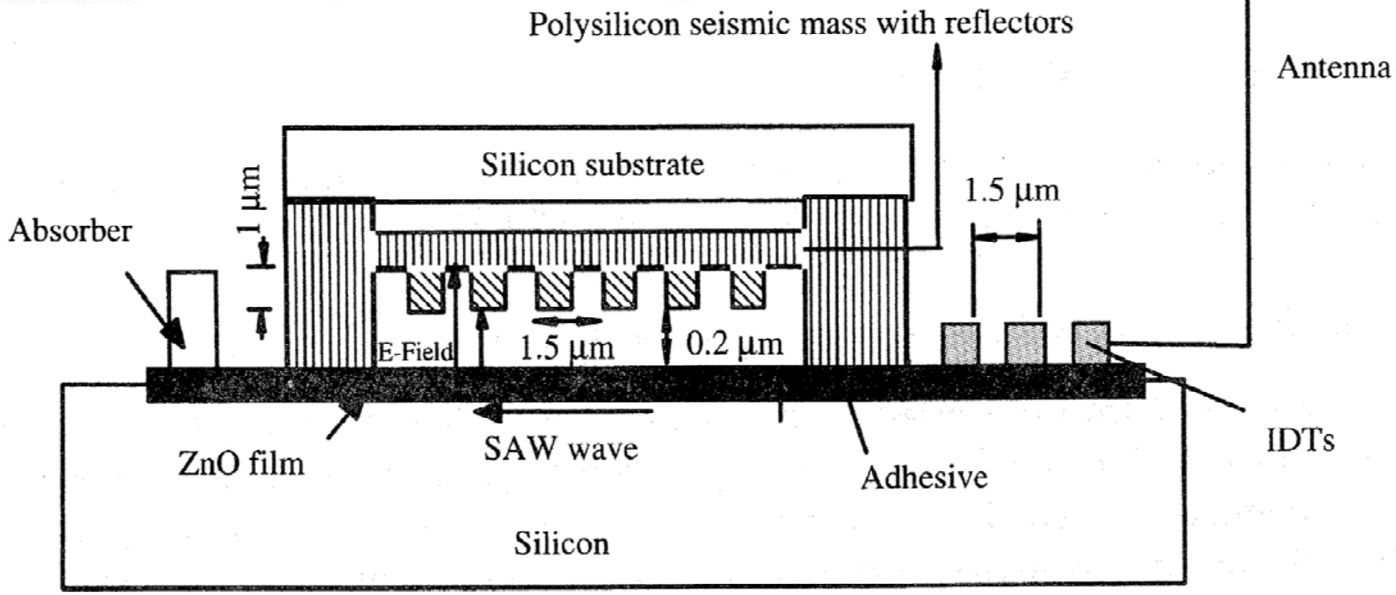
Wireless SAW-based microsensors

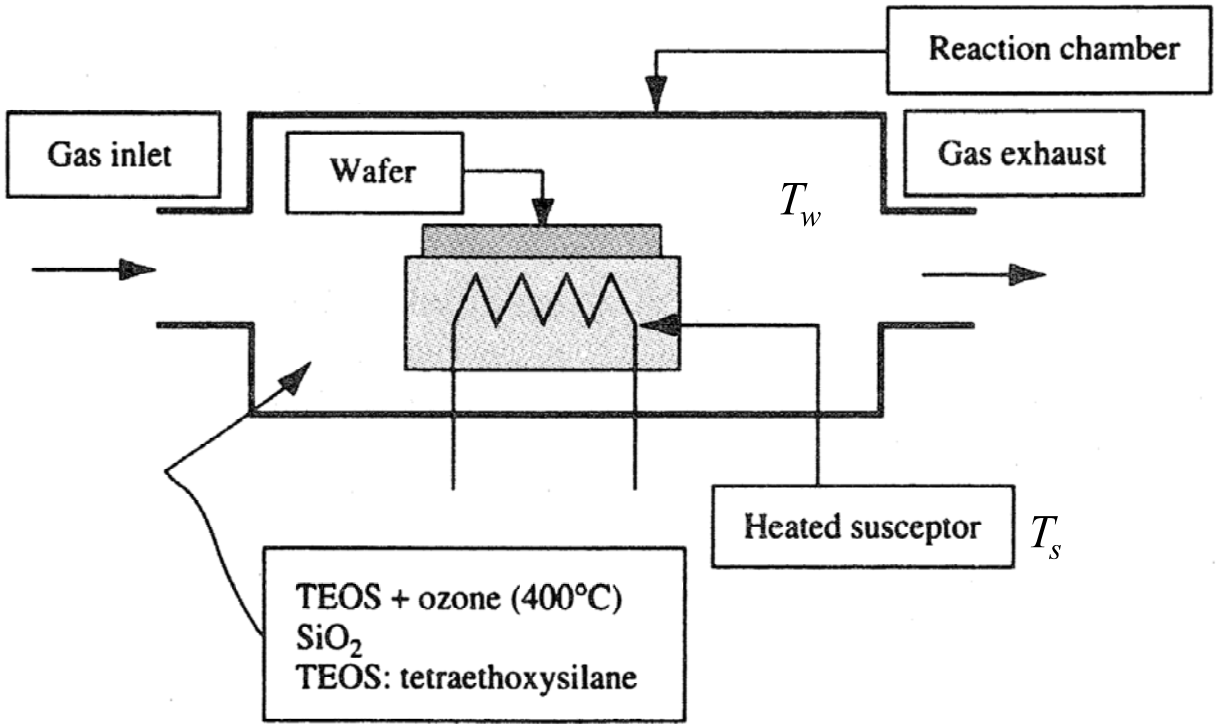




MEMS-IDT Microsensors






Reaction chamber
Gas inlet
Wafer
Gas exhaust
T_w
Heated susceptor
T_s
TEOS + ozone (400°C)
SiO_2
TEOS: tetraethoxysilane